DRAFT

Booster Corrector Measurements

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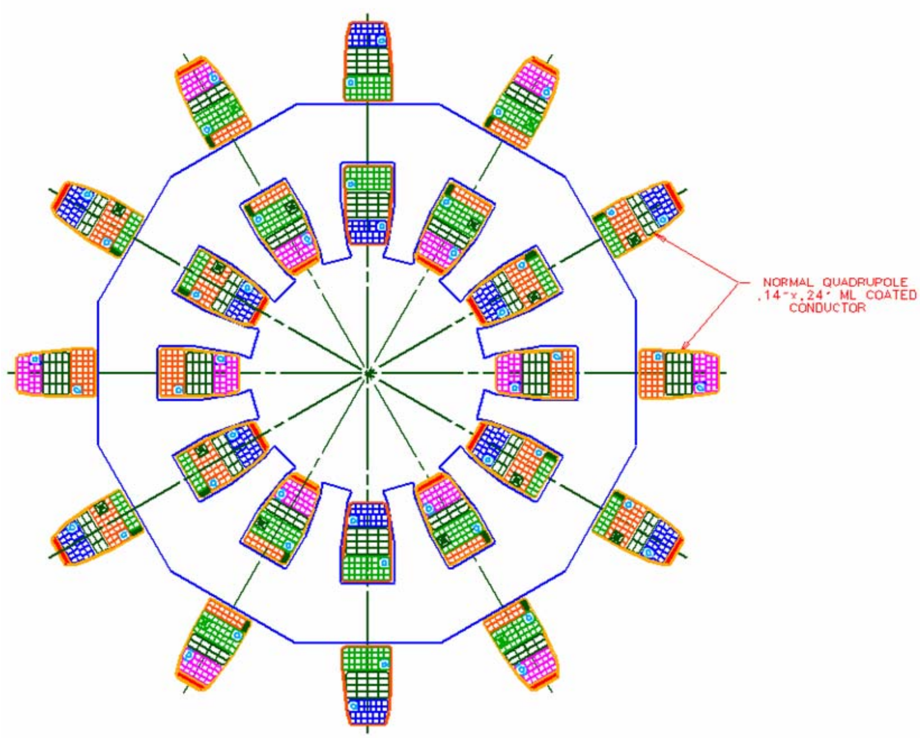
TD has undertaken to design and assemble a set of new correction elements for the Booster. These magnets will require testing at the Magnetic Test Facility. As usual, there will be a prototype phase and a production phase with different requirements.

Magnet description

One corrector package (series BMA) consists of a horizontal dipole, a vertical dipole, a normal quadrupole, a skew quadrupole, a normal sextupole, and a skew sextupole. The total package length (flange-to-flange) is about 17”. The core length is 10.5”. The pole tip radius is 69.4 mm (2.732”). The outer diameter of the beam tube is 5.25”; the inner diameter is about 5.23”. The good field region diameter is 4.5”.

Being a part of the Booster, the magnet will run on a 15 Hz cycle. Some components are specified to switch polarity, at full field, within 1 ms. To minimize heating, the typical excitation curve will run from a low level to full on in 33 ms (1/30 sec), possibly with a polarity change in the middle, then turn off in a few milliseconds. The maximum design full current is about 70 A peak, 50 A rms, for the normal quadrupole. Calculated resistances and inductances are being reviewed and should be available soon. Other circuits are lower. In operation all six components will be running simultaneous with different ramps.



The conductor is copper with varying cross sections: 0.14”x0.24” rectangular, 0.128” square, 0.064” round Heat dissipation should be under 2 kW. Water flow is 1 gpm. Water temperature rise is under 10 ºC.

Fabrication plan

Two prototype coils have already been fabricated and tested for thermal properties.

A second pair of prototype coils will be fabricated to the intended production design for a second thermal test. These are scheduled for delivery in January 2006.

A prototype full magnet is scheduled for delivery in May 2006. Some magnetic testing may be requested in April 2006.

The first production magnet is scheduled for December 2006.

Magnet production is planned to extend from January through August 2007 at a rate of two magnets per week.

Prototype measurements

1) Coil prototype thermal measurements

We have already conducted a thermal test on two initial prototype coils. Due to a substantial redesign, two more coils will be fabricated for another thermal test. The second test coils will have thermocouples buried in the coils as well as requiring external temperature monitoring and coil resistance measurements in the fashion to which MTF has become accustomed. For the initial test, all the windings were bussed in series and a single supply powered the whole test DC. This will probably be sufficient for second test.

2) In-process magnetic measurement.

Pending further discussion, we may request DC magnetic field measurements of the prototype magnet before the whole magnet is potted in order to verify the bussing. For this purpose, powering and measuring a single element at a time would be sufficient. The primary goal here would be to verify that the fields have the right harmonic composition, indicating that the magnet is wired correctly. This would also provide a first confirmation of the calculated field strengths and purity. There would be no beam tube present.

3) Prototype magnet thermal measurements

The whole magnet prototype will require same thermal testing. With the availability of separate power supplies for the magnetic testing, it may be interesting to conduct a more complex thermal test of individual elements.

4) Prototype magnetic measurements.

a) DC measurements with a single element excited. An excitation curve and harmonics at multiple currents will be desired at currents up to the rms limit for each of the six elements by themselves. If the probe diameter does not adequately cover the good field region, offset measurements will be needed to map the whole field. These measurements will be without beam tube.

b) DC measurements with multiple elements excited. These measurements will require multiple power supplies controlled independently. Ideally, we would measure the field components with each of the elements power on positive, off, and on negative, with the current level set as the maximum rms current allowed for the element in operation.

This would give a total of 729 measurements, more if we need off center measurements. The exact program will require negotiation.

c) AC measurements with a single element excited. In order to reach the full operating currents and to understand the response of the magnet to operating conditions, measurements of the integrated strength and field components are required as a function of time and current through a typical operating ramp. With large current swings occurring in 1 ms, the sampling rate must be at least ten times that. On the assumption that the magnet behaves the same on each cycle, harmonics data can be gathered over multiple cycles with the probe in different orientations. Initial measurements will be without a beam tube.

d) AC measurements with a single element excited. In order to reach the full operating currents and to understand the response of the magnet to operating conditions, measurements of the integrated strength and field components are required as a function of time and current through a typical operating ramp. With large current swings occurring in 1 ms, the sampling rate must be at least ten times that. On the assumption that the magnet behaves the same on each cycle, harmonics data can be gathered over multiple cycles with the probe in different orientations. Initial measurements will be without a beam tube.

e) AC measurements with multiple elements excited. In order to understand the response of the magnet to operating conditions, measurements of the integrated strength and field components are required as a function of time and current through a typical operating ramp with various combinations of elements excited, each on its own ramp. With large current swings occurring in 1 ms, the sampling rate must be at least ten times that. Fast swings that may lag each other by less than 1 ms would require an even fast sampling rate. On the assumption that the magnet behaves the same on each cycle, harmonics data can be gathered over multiple cycles with the probe in different orientations. The exact ramps and most interesting combinations will be specified by AD. Initial measurements will be without a beam tube.

f) AC Magnetic center. Determine the magnetic center of each of the quadrupoles and the sextupoles independently operating the magnet AC. Determine whether the center shifts with multiple elements excited in typical combinations.

g) AC measurements with multiple elements excited and a beam tube. These are the same measurements as before, repeated with a beam tube installed to assess the effect of eddy currents in the beam tubes and BPM’s.

h) AC Magnetic center with beam tube. Determine the magnetic center of each of the quadrupoles and the sextupoles independently operating the magnet AC with the beam tube installed. Determine whether the center shifts with multiple elements excited in typical combinations.

Production measurements

1) In-process field measurement. It would be valuable to have a system to verify that every one of the 46 internal electrical connections has been made correctly before the assembly is potted. There will be 12 leads (two per element). For example, a controller

might switch a single power supply onto each of the six pairs while an array of Hall probes, one on each pole, registered the field. Alternatively, if the applied current were AC, one small coil for each pole could pick up the field. In either case we would be very sensitive to sign/phase.

2) Final field measurements. As trim magnets, we may not require a full set of measurements on each magnet. On at least a sample of magnets we will certainly want to repeat the AC measurements with multiple elements excited and a beam tube to get a sense of the distribution of parameters.

3) AC magnetic center. On at least a sample of magnets we will certainly want to measure the magnetic centers of the various elements.

Technical comments

1) AD/EES has said that they can provide power supplies for the multi-supply and AC testing. We need to work with them to understand the appropriate current monitoring and ramp controllers.

2) The rapid cycling and the need for measurement of harmonic components suggest the use of a rotating coil indexed from one position to the next for successive excitations. The volume of data will require development of automated processing tools before the arrival of the first magnet.

3) With interest spread over multiple harmonics, we need to think about the proper probe(s) for this measurement. A tangential coil may be preferred to a Morgan coil to reduce the number of probe rotations required for each configuration. The higher order multipoles that are interesting, the lack of sextupole bucking on existing Morgan coils, and fairly relaxed precision requirements support this choice.

4) Thought is needed regarding the measurement precision required.